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September 1968

NAVWEARSCHFAC Technical Paper No. 19-68

DETERMINATION OF BALLISTIC WINDS FOR ROCKET-ASSISTED PROJECTILES (RAP)

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SEPTEMBER 1968

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BACKGROUND

A projectile fired into the atmosphere is affected by the wind from the time it leaves the muzzle of the gun until the time of impact. The total effect on the projectile's trajectory depends upon the wind direction and speed, and the air density encountered along the entire trajectory. However, for simplicity, density is normally considered to be equal to some assumed standard, while computing the effect of wind at each point along the trajectory. A separate computation is then made to determine a "ballistic density", which will essentially compensate for departures of density from the assumed standard.

In computing the effect of the wind for naval gunfire, the common practice consists of computing the speed and direction of a uniform or ballistic wind which would have essentially the same effect upon the projectile trajectory as would the actual wind encountered.

When firing most conventional ammunition, it is sufficient to determine the mean wind for each of a succession of vertical zones or strata. From these zonal winds, a vector mean is determined by applying weighting factors appropriate to each zone traversed by the trajectory from gun to point of impact. The appropriate weighting factors depend, of course, upon whether the fire is directed at surface targets or aircraft. They depend also upon whether the zones are of uniform vertical extent, for example, 2,500-foot zones, or are of varying thicknesses, e.g., successively, 200 meters, 300 meters, 500 meters, etc.

A comprehensive discussion of the general ballistic problem is contained in the WEARSCHFAC publication "Meteorological Ballistics," NWRF 42-0665-105, June 1965. Upon the issuance of that publication, however, the rocket-assisted projectile had not yet been developed. It is now known, that these projectiles tend to cock into the wind in a manner similar to that of unguided rockets.

Thus, with RAP, the effect of a specific wind component in the direction of the fire and of a similar wind component in the cross-fire direction are so different, that it becomes necessary to use two differing weights for each zone. One weighting factor is required to compute the effect on range, and the other to compute the effect on lateral drift. This, in turn, means that the resultant ballistic wind depends not only upon the maximum ordinate or number of zones to be traversed and the wind in these zones, but also upon the direction of fire.

DETERMINING THE RAP BALLISTIC WIND

Given the mean zonal wind and the appropriate set of weighting factors from the surface to the maximum ordinate (or antiaircraft target elevation), the ballistic wind may be computed in two distinct stages:

I. A. Computing the resultant range-wind effect - RAP RANGE WIND.

B. Computing the resultant cross-wind effect - RAP CROSS WIND.

II. A. Finding the respective components of the RAP range and cross winds in line with and perpendicular to the direction of fire.

B. Combining these components along and across the line of fire into a resultant ballistic wind.

It should be observed that the first-stage computations can be completed for a number of preselected locations and for each of several prospective maximum ordinates prior to determination of the direction of fire, as might routinely be done by a supporting NAVWEASERV unit afloat or ashore. From the results of the first stage, the second-stage computations can be completed quickly and effectively by a graphic solution on a maneuvering board once the direction of fire is known.

Stage I. A. RAP RANGE WIND (RAPRW)

The RAPRW for any one required maximum ordinate is computed by the following steps:

1. Determine the mean wind for each successive 2,500-foot zone from the surface to the maximum ordinate of the highest trajectory anticipated.

2\. a. Multiply each zonal wind speed from the surface zone to the maximum ordinate by the corresponding RANGE-WIND WEIGHTING FACTOR.

b. Form the vector resultant of these weighted zonal winds, the same manner as for determination of the total ballistic wind for conventional gunfire. (Aerological plotting board is helpful).

The RAPRW is the final resultant of step 2. b. It is a vector, and therefore consists of both direction and speed.

Stage I. B. RAP CROSS WIND (RAPXW)

The RAPXW is computed in exactly the same manner as the RAPRW, but using the corresponding CROSS-WIND WEIGHTING FACTOR instead of the range-wind factor. It is important here to notice, that owing to a tendency on the part of rocket-assisted projectiles to wind cock, negative numbers appear for RAP cross-wind weighting factors in some instances.

In graphically constructing the resultant vector, the winds for zones having negative weighting factors must be represented by a length directed opposite to the direction of the wind for those zones.

Following the directions of stage I, two ballistic winds are determined. Each is in a way analogous to a complete ballistic wind. They will in general differ in magnitude, and may differ materially in direction if there is much turning of the wind with height (as commonly occurs in SEASIA at the height of both the Northeast and Southwest Monsoons). They must, however, be used together to determine the final ballistic wind for a particular direction of fire. Neither one tells the story alone.

STAGE II. RAP BALLISTIC WIND (RAPBW)

The RAPBW is found for any required direction of fire by determining the resultant of the range-wind effect (RAPRW) and the cross-wind effect (RAPXW) for the specified direction.

Consider first the range-wind effect, as represented by the vector RAPRW on the maneuvering board shown in figure 1. Here, the vector RAPRW depicts a range-wind direction (from which blowing) of 240° and a range-wind speed of 60 knots. The end point of the vector RAPRW is located at the center of the maneuvering board. Draw a circle centered at the midpoint of this vector and having the diameter RAPRW (radius equal to half the magnitude of RAPRW). The circle, marked R in figure 1, will then pass through both ends of RAPRW (and therefore also through the center of the maneuvering board). The intersection of the target bearing (direction of fire) line drawn through the center of the maneuvering board and circle R defines the component of RAPRW along that direction of gunfire. In particular, for a target bearing in this example of 60° or 240°, the fire is along RAPRW; hence, the range-wind component is identical to RAPRW, that is, 240°, 60 knots. Along a direction perpendicular to RAPRW, i.e., 150° or 330° in this example, the range-wind component is zero. For any other bearing, as in direction B, or B', the component of the RAPRW along the direction of fire is given by the vector from the intersection of the line BB' with the circle R to the center of the diagram, in this case 20 knots from 170°. (The dashed line completing a right triangle illustrates this.)

Consider now the cross-wind effect, as represented by the vector RAPXW on the maneuvering board shown in figure 2. Here, the vector RAPXW depicts a cross-wind direction of 210°, 40 knots. A circle having a diameter RAPXW is constructed about the mid-point of RAPXW and labeled X. To find the cross-wind effect, one draws a line through the center of the maneuvering board perpendicular to the line of fire, and finds its intersection with circle X. Again, there is a direction along which the component is zero and a direction along which the cross-wind effect will be a maximum. For example, if the desired direction of fire is the same as that given by the line BB' of figure 1, draw the line NN' on figure 2 perpendicular to BB' and through the center of the maneuvering board. The cross-wind component is the vector <u>from</u> the intersection of the line NN' with the circle X <u>to</u> the center of the maneuvering board, in this example 26 knots <u>from</u> 260°.

The range-wind component can now be combined with the cross-wind component to provide a resultant RAP BALLISTIC WIND (RAPBW) which describes both the range-wind and the cross-wind effects for this target bearing.

Figure 3 shows a graphic combination of the components as determined on figures 1 and 2. It illustrates stage II complete in one plot, as carried out by the following steps.

A. 1. Plot RAPRW as a wind vector with its end point at the center of the diagram, O.
Construct circle R centered at its midpoint with RAPRW as a diameter.

2. Plot RAPXW as a wind vector with its end point at the center of the diagram, O.
Construct circle X centered at its midpoint with RAPXW as a diameter.

3. Draw in line BB' toward and opposite the target bearing. Mark its intersection with circle R as r.

4. Draw in line NN' perpendicular to BB'. Mark its intersection with circle X as x.

B. 1. Form a resultant for the vector components rO and xO, where O represents the center of the plot as indicated above. (This may be done by completing the rectangle for which 3 of the corners are defined by O, r, and x.)

2. Read the direction from which this resultant blows, and its speed. This is the RAP ballistic wind (RAPBW) for this particular target bearing.

The same procedure will determine a RAPBW for any other target bearing.

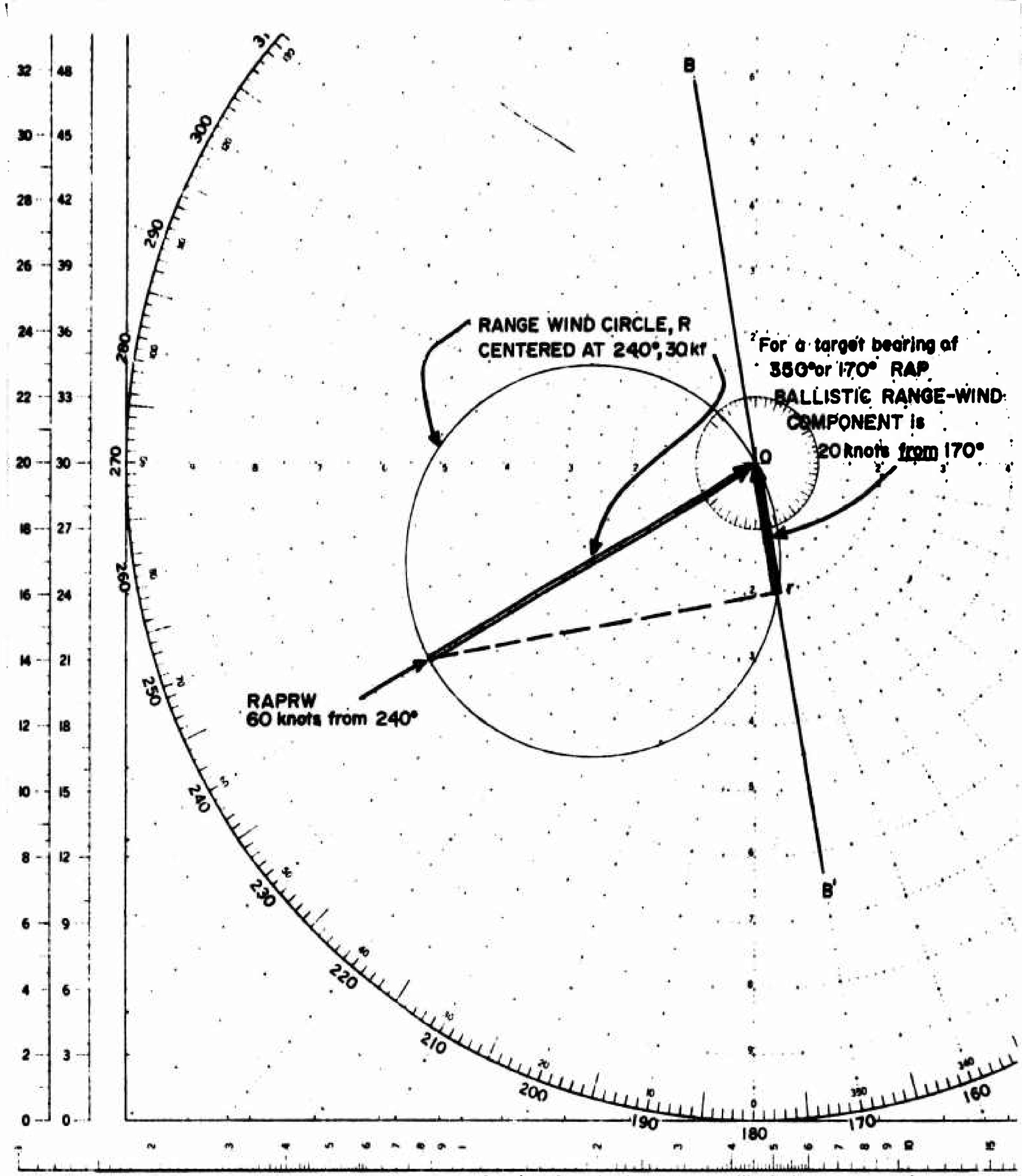

Figure 1. Graphical Determination of RAP Ballistic Range-Wind Component for a Given RAP Range Wind (RAPRW) and a Given Direction of Fire (BB').

Given any two corresponding quantities, solve for third by laying rule through points on proper scales and read intersection on third scale

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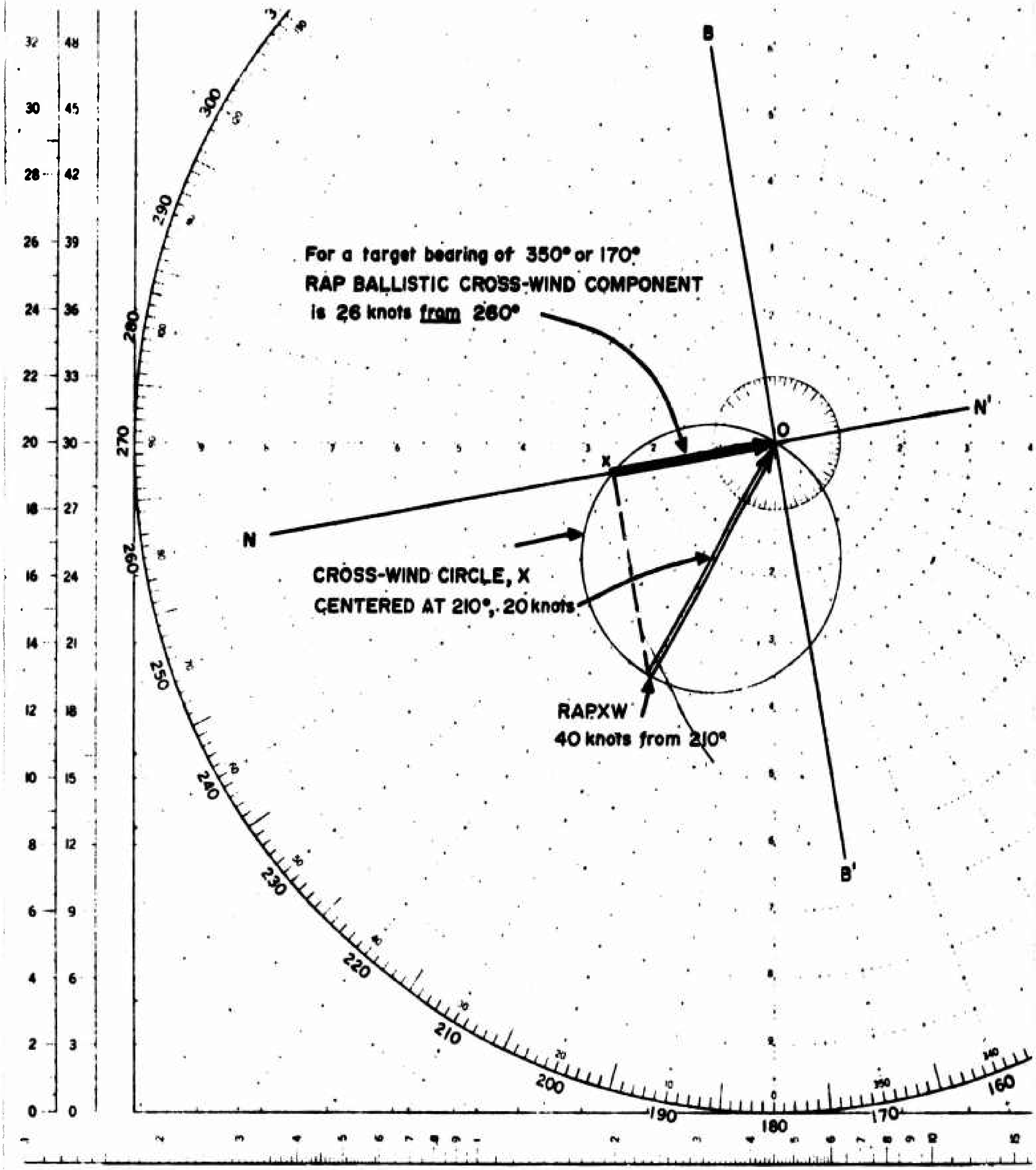

Figure 2. Graphical Determination of RAP Ballistic Cross-Wind Component for a Given RAP Cross Wind (RAPXW) and a Given Direction of Fire (BB').

Given any two corresponding quantities, solve for third by laying rule through points on proper scales and read intersection on third scale.

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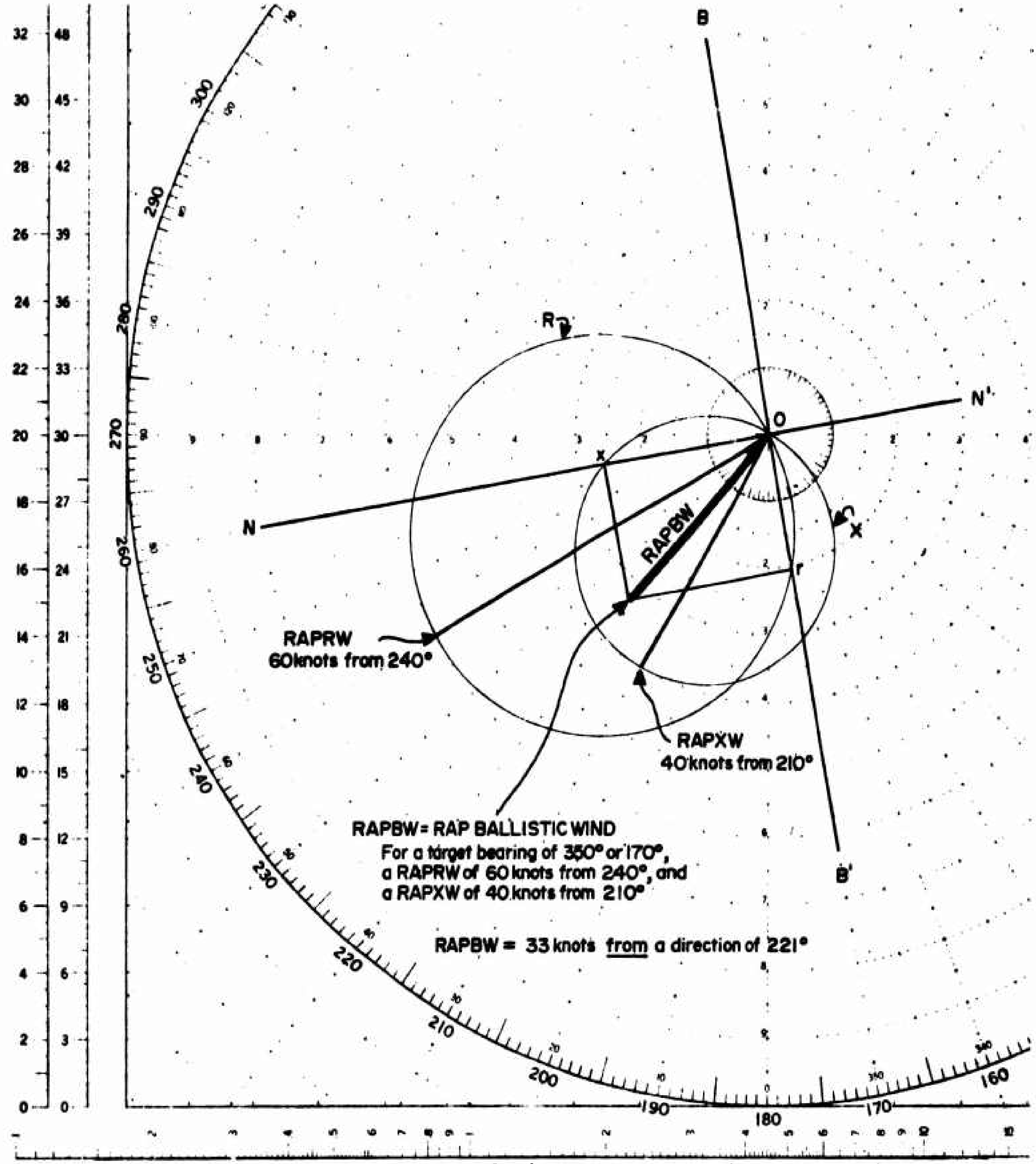

Figure 3. Graphical Determination of RAP Ballistic Wind for a Given RAP Range-Wind Component (RAPRW), RAP Cross-Wind Component (RAPXW) and Direction of Fire (BB').

Given any two corresponding quantities, solve for third by laying rule through points on proper scales and read intersection on third scale.

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